SUSE

Running Real-Time Applications in Container Environments

Running real-time applications within Docker or Podman containers on SUSE Linux Enterprise Server requires deterministic scheduling, kernel tuning and CPU shielding. Because containers share the host kernel, manually isolating real-time processes into dedicated cgroups prevents interference from background host tasks. This optimization reduces worst-case latency and helps critical workloads maintain predictable execution without thread starvation.

Prerequisites

- Installed real-time kernel
- Installed Docker or Podman environment

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1 Understanding real-time constraints in containers

When deploying real-time (RT) workloads within containers, it is crucial to understand the limitations of container boundaries. Containers do not provide strict enough isolation to guarantee zero cross-talk, meaning your real-time processes will inevitably be affected by background container activity.

From the perspective of the RT kernel, a container is another process. There are no container-specific settings to eliminate interference, regardless of whether it originates inside or outside a container. You should also be prepared for this interference to increase significantly if you attempt to run multiple RT applications across separate containers.

While using an RT kernel improves your worst-case latency compared to a standard SLES environment, the inherent overhead required to achieve determinism means it will not necessarily outperform a standard `NOPREEMPT` kernel in raw throughput. Keep these constraints in mind as you prepare and shield your containerized workloads in the following steps.

2 Running RT applications in Docker containers

If you intend to run compute-intensive applications with real-time priority, you must make sure that kernel threads cannot starve. (This is general advice that applies to other real-time scenarios as well.)

2.1 Prerequisites

A simple precaution is to use the `rtkthread=PRIORITY` and `rtworkqueues=PRIORITY` kernel boot parameters. Set the `PRIORITY` values higher than the priority of any process that has the potential to dominate a CPU. This is not strictly real-time capable, but it is safer overall.

On top of those kernel boot parameters, the following conditions must be met:

- The kernel must be booted with the `nortsched` command-line parameter to hide cgroup scheduling from the container engine.
- The **`docker run`** or **`podman run`** command must be issued with the `--privileged=true` parameter.
- The container is equipped with the `chrt` system tool.

2.2 Starting real-time application containers

To start a container without isolation, run the command **`docker run`** or **`podman run`** using `chrt` to set the RT class or priority of the program you execute when starting the container. For example:

```
> sudo docker run --privileged=true ... /usr/bin/chrt -f 1 /usr/sbin/sshd -D
```

Alternatively:

```
> sudo podman run --privileged=true ... /usr/bin/chrt -f 1 /usr/sbin/sshd -D
```

The above starts `sshd` within the container as a `SCHED_FIFO` task of priority 1. If you SSH into it, any command or application run in the container inherits the scheduler's RT class and priority.

3 Shielding containers

Currently, Docker or Podman do not provide a built-in mechanism to launch a container directly into a highly isolated CPU set (cpuset). To achieve true deterministic performance for real-time workloads, you must perform this isolation manually.

The process involves two primary phases:

- **Establishing the shield:** Creating an isolated cgroup partition and moving all host system processes (using `systemd`) away from your dedicated real-time CPUs.
- **Migrating the container:** Launching the container, and then manually migrating its processes into the newly isolated cgroup.

3.1 Establishing the shield

The following shell script brings an isolated shield up or down. It restricts default system services to CPUs 0-3, routes interrupts away from the real-time cores, and creates an isolated partition (`/sys/fs/cgroup/rtcpus`) for CPUs 4-63.

```
#!/bin/sh
# ----------------------------------------------------------------------
# Toggle script for establishing a cgroups v2 real-time shield
# ----------------------------------------------------------------------

let START_CPU=4
let END_CPU=63
let ONLINE=1
```

```
let SHIELD_UP=0
GOVERNOR="performance"

# Masks for routing interrupts
DEFAULT_MASK=ffffffff,ffffffff
SHIELD_MASK=00000000,0000000f # CPUs 0-3

CGROUP2_ROOT="/sys/fs/cgroup"
SHIELD_CG="${CGROUP2_ROOT}/rtcpus"

# Capture kernel settings
if [ -f /proc/sys/kernel/sched_rt_runtime_us ]; then
  RT_RUNTIME=$(cat /proc/sys/kernel/sched_rt_runtime_us)
fi
if [ -f /proc/sys/kernel/nmi_watchdog ]; then
  NMI_WATCHDOG=$(cat /proc/sys/kernel/nmi_watchdog)
fi

# Detect if the shield is already active
if [ -d "$SHIELD_CG" ]; then
  let SHIELD_UP=1
fi

if [ $SHIELD_UP -eq 1 ]; then
  echo "Tearing down cgroup v2 shield..."

  # 1. Dismantle the isolated partition
  if [ -f "${SHIELD_CG}/cpuset.cpus.partition" ]; then
    echo "member" > "${SHIELD_CG}/cpuset.cpus.partition" 2>/dev/null
  fi

  # 2. Move any leftover tasks back to the root cgroup
  if [ -f "${SHIELD_CG}/cgroup.procs" ]; then
    for pid in $(cat "${SHIELD_CG}/cgroup.procs" 2>/dev/null); do
      echo $pid > "${CGROUP2_ROOT}/cgroup.procs" 2>/dev/null
    done
  fi

  # 3. Remove the custom cgroup
  rmdir "$SHIELD_CG" 2>/dev/null

  # 4. Restore systemd slices to use all CPUs
  systemctl set-property --runtime system.slice AllowedCPUs=0-63
  systemctl set-property --runtime user.slice AllowedCPUs=0-63
  systemctl set-property --runtime init.scope AllowedCPUs=0-63

  # Restore default IRQ affinity
```

```
  echo ${DEFAULT_MASK} > /proc/irq/default_smp_affinity
  for irqlist in $(ls /proc/irq/*/smp_affinity 2>/dev/null); do
    echo ${DEFAULT_MASK} >$irqlist 2>/dev/null
  done

  # Restore kernel tuning (Timers, Hugepages, Watchdogs, etc.)
  [ -f /proc/sys/kernel/timer_migration ] && echo 1 > /proc/sys/kernel/timer_migration
  [ -f /proc/sys/kernel/sched_rt_runtime_us ] && echo ${RT_RUNTIME} > /proc/sys/kernel/
sched_rt_runtime_us
  [ -f /sys/kernel/debug/tracing/tracing_on ] && echo 1 > /sys/kernel/debug/tracing/
tracing_on
  [ -f /sys/kernel/mm/transparent_hugepage/enabled ] && echo always > /sys/kernel/mm/
transparent_hugepage/enabled
  [ -f /proc/sys/kernel/nmi_watchdog ] && echo ${NMI_WATCHDOG} > /proc/sys/kernel/
nmi_watchdog
  [ -f /sys/devices/system/machinecheck/machinecheck0/check_interval ] && echo 300 > /
sys/devices/system/machinecheck/machinecheck0/check_interval
  [ -f /sys/devices/virtual/workqueue/writeback/cpumask ] && echo ${DEFAULT_MASK} > /sys/
devices/virtual/workqueue/writeback/cpumask
  [ -f /sys/devices/virtual/workqueue/cpumask ] && echo ${DEFAULT_MASK} > /sys/devices/
virtual/workqueue/cpumask
  [ -f /proc/sys/vm/stat_interval ] && echo 1 > /proc/sys/vm/stat_interval
  [ -f /sys/module/processor/parameters/latency_factor ] && echo 2 > /sys/module/
processor/parameters/latency_factor
  [ -f /sys/module/processor/parameters/ignore_ppc ] && echo 0 > /sys/module/processor/
parameters/ignore_ppc
  [ -f /sys/module/processor/parameters/ignore_tpc ] && echo 0 > /sys/module/processor/
parameters/ignore_tpc

  if [ -f /etc/init.d/sgi_irqbalance ]; then
   /etc/init.d/sgi_irqbalance start
  elif systemctl is-active --quiet irqbalance; then
    systemctl start irqbalance
  fi

else
  echo "Bringing up cgroup v2 shield..."

  # Route IRQs away from shielded CPUs
  if [ -f /etc/init.d/sgi_irqbalance ]; then
    /etc/init.d/sgi_irqbalance stop
  else
    systemctl stop irqbalance 2>/dev/null
  fi

  echo $SHIELD_MASK > /proc/irq/default_smp_affinity
  for irqlist in $(ls /proc/irq/*/smp_affinity 2>/dev/null); do
```

```
    echo $SHIELD_MASK >$irqlist 2>/dev/null
  done

  # Apply Real-Time kernel tuning (Disable tracing, THP, watchdogs, etc.)
  [ -f /proc/sys/kernel/sched_rt_runtime_us ] && echo -1 > /proc/sys/kernel/
sched_rt_runtime_us
  [ -f /sys/kernel/debug/tracing/tracing_on ] && echo 0 > /sys/kernel/debug/tracing/
tracing_on
  [ -f /sys/kernel/mm/transparent_hugepage/enabled ] && echo never > /sys/kernel/mm/
transparent_hugepage/enabled
  [ -f /proc/sys/kernel/nmi_watchdog ] && echo 0 > /proc/sys/kernel/nmi_watchdog
  [ -f /sys/devices/system/machinecheck/machinecheck0/check_interval ] && echo 0 > /sys/
devices/system/machinecheck/machinecheck0/check_interval
  [ -f /sys/devices/virtual/workqueue/writeback/cpumask ] && echo ${SHIELD_MASK} > /sys/
devices/virtual/workqueue/writeback/cpumask
  [ -f /sys/devices/virtual/workqueue/cpumask ] && echo ${SHIELD_MASK} > /sys/devices/
virtual/workqueue/cpumask
  [ -f /proc/sys/vm/stat_interval ] && echo 999999 > /proc/sys/vm/stat_interval
  [ -f /sys/module/processor/parameters/latency_factor ] && echo 1 > /sys/module/
processor/parameters/latency_factor
  [ -f /sys/module/processor/parameters/ignore_ppc ] && echo 1 > /sys/module/processor/
parameters/ignore_ppc
  [ -f /sys/module/processor/parameters/ignore_tpc ] && echo 1 > /sys/module/processor/
parameters/ignore_tpc

  # 1. Restrict default system tasks to non-shielded CPUs using systemd
  systemctl set-property --runtime system.slice AllowedCPUs=0-3
  systemctl set-property --runtime user.slice AllowedCPUs=0-3
  systemctl set-property --runtime init.scope AllowedCPUs=0-3

  # 2. Fire up the shield using native cgroups v2
  mkdir -p "$SHIELD_CG"

  # Ensure the cpuset controller is enabled in the subtree
  echo "+cpuset" > "${CGROUP2_ROOT}/cgroup.subtree_control" 2>/dev/null || true

  # Assign the real-time CPUs to our shield
  echo "${START_CPU}-${END_CPU}" > "${SHIELD_CG}/cpuset.cpus"

  # Set the partition to 'isolated' (disables load balancing across these CPUs)
  if [ -f "${SHIELD_CG}/cpuset.cpus.partition" ]; then
    echo "isolated" > "${SHIELD_CG}/cpuset.cpus.partition"
  fi

  # Allow time for the kernel sched_domain to rebuild
  sleep 1
```

```
  # Offline/online cycle to migrate timers and kthreads off shielded cores
  if [ $ONLINE -eq 1 ]; then
    for i in `seq ${START_CPU} ${END_CPU}`; do
      echo 0 > /sys/devices/system/cpu/cpu$i/online
      echo 1 > /sys/devices/system/cpu/cpu$i/online
    done

    # Prioritize re-initialized kthreads
    systemctl restart set_kthread_prio 2>/dev/null || true
  fi

  if [ -f /proc/sys/kernel/timer_migration ]; then
    echo 0 > /proc/sys/kernel/timer_migration
  fi

  GOVERNOR="performance"
fi

# Set CPUFreq scaling governor
if [ -f /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor ]; then
  CURRENT_GOVERNOR=$(cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor)
  if ! [ "$GOVERNOR" = "$CURRENT_GOVERNOR" ]; then
    for i in $(ls /sys/devices/system/cpu/cpu*/cpufreq/scaling_governor 2>/dev/null); do
      echo $GOVERNOR >$i
    done
  fi
fi
```

3.2 Migrating the container into the shield

Once your `rtcpus` isolated cgroup is actively running, you can launch your container workload. The workflow below demonstrates how to initialize the container and seamlessly transfer its PID into the shielded partition.

The scripts below use the script created in the previous section called `shield.sh`. If you named it differently, please adjust the code below accordingly.

In the case of Docker, run the following script.

```
# 1. Execute the shield script to isolate CPUs 4-63
./shield.sh

# 2. Launch your real-time container in the background
docker_id=$(docker run -d --privileged=true my_rt_image /usr/bin/chrt -f 1 /path/to/
my_app)
```

```
# 3. Extract the root Process ID (PID) of the running container
container_pid=$(docker inspect -f '{{.State.Pid}}' ${docker_id})

# 4. Migrate the container into the isolated cgroup
# Moving the root PID automatically migrates its child threads in v2
echo ${container_pid} > /sys/fs/cgroup/rtcpus/cgroup.procs

# --- Workload is now running on isolated RT CPUs ---

# 5. Clean up when finished: Stop and remove the container
docker stop ${docker_id}
docker rm ${docker_id}

# 6. Tear down the shield and restore normal system scheduling
./shield.sh
```

In the case of Podman, run the following script:

```
# 1. Execute the shield script to isolate CPUs 4-63
./shield.sh

# 2. Launch your real-time container in the background (Must use sudo for Rootful mode)
# NOTE: The --annotation argument is required in cgroups v2 to allocate RT runtime
 budget.
podman_id=$(sudo podman run -d \
  --privileged \
  --annotation run.oci.cgroup.cpu.rt_runtime=950000 \
  my_rt_image /usr/bin/chrt -f 1 /path/to/my_app)

# 3. Extract the root Process ID (PID) of the running Podman container
container_pid=$(sudo podman inspect -f '{{.State.Pid}}' ${podman_id})

# 4. Migrate the container into the isolated cgroup
# Moving the root PID automatically migrates its child threads in v2
echo ${container_pid} | sudo tee /sys/fs/cgroup/rtcpus/cgroup.procs

# --- Workload is now running on isolated RT CPUs (4-63) ---

# 5. Clean up when finished: Stop and remove the container
sudo podman stop ${podman_id}
sudo podman rm ${podman_id}

# 6. Tear down the shield and restore normal system scheduling
./shield.sh
```



Note: Child processes are shielded by default

By writing the container's root PID into the `cgroup.procs` file of the shielded cgroup, the unified hierarchy automatically tracks and confines all spawned child threads to your designated real-time CPUs.

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